

CALIFORNIA DIVISION OF MINES AND GEOLOGY

FAULT EVALUATION REPORT FER-171

San Andreas Fault

(Middle Mountain-Cholame Valley Segment)

and

San Juan Fault (North End)

Monterey and San Luis Obispo Counties, California

by

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INTRODUCTION

Previously-zoned traces of the San Andreas fault and San Juan fault within the Cholame, Cholame Valley, Cholame Hills, Parkfield, and Stockdale Mountain 7.5 minute quadrangles have been examined as part of CDMG's Fault Evaluation Program. These fault traces were zoned in 1974 as specified in the Alquist-Priolo Special Studies Zones Act (see Hart, 1985, p 2). Zoning criteria at that time were more liberal than at present; specifically, all Quaternary faults within those quadrangles that contained the San Andreas fault were included within Special Studies Zones. Age-classification of fault traces was based entirely on available geologic mapping and reports. Present evaluation procedures include both a review of the pertinent literature and air photo interpretation, with field inspection of selected fault traces. Only those fault segments determined to meet the necessary criteria of "sufficiently active and well-defined" will be included by the State Geologist in the revised zones (see Hart, 1985, p. 5-6).

SUMMARY OF AVAILABLE DATA

San Andreas fault

The San Andreas fault extends northwestward across California for more than 600 miles (960 km), from the Salton Sea to Point Arena. The fault traverses the ocean floor for about 74 miles (118 km) northward from Point Arena before crossing the Point Delgada peninsula near Shelter Cove (Jennings, 1975). The fault consists of numerous en echelon or subparallel fault strands, most of the strands being right-lateral strike-slip faults. According to Sieh and Jahns (1984, p. 883), approximately 300 km (190 miles) of right-lateral displacement has taken place since mid-Miocene time (15 million years B.P.).

The Parkfield-Cholame segment of the San Andreas fault is apparently the most active segment in terms of historic earthquakes, which include large to major events in 1857, 1901, 1922, 1934, and 1966. Fault creep has been noted

locally (Brown and others, 1967; Nason, 1971; Schulz and Burford, 1979)). This segment of the fault is probably the most intensely-studied fault segment in the world (E.W. Hart, personal communication, 1985). Due to the limited scope of this study, the voluminous literature on the San Andreas fault will not be reviewed. Only the pertinent geologic mapping will be examined.

The existing Special Studies Zones (SSZ) within these five quadrangles (CDMG, 1974) are based on mapping by Brown (1970), Brown and others (1967), Dibblee (1971a, 1971b, 1972), and Dickinson (1966). Initial zoning was not restricted to those faults that are "sufficiently active and well-defined" surface traces as required by current standards, but was applied to all Quaternary-age faults. Due to time constraints during the initial zoning, no verification of fault location or activity was attempted by CDMG staff. The various source maps had a small scale (1:62,500 or smaller), a planimetric base, or both, and the fault traces on the SSZ maps may be mislocated. Other faults were inferred or poorly defined, and some of the zoned faults may not meet our current zoning criteria.

Brown and others (1967) describe the surface effects, including fault rupture, associated with a series of seven moderate earthquakes ($M_R = 3.5$ to 5.5) near Parkfield and Cholame Valley during June-August 1966. Surface rupture occurred along a 23.5 mile-long segment of the main strand of the San Andreas fault, and also along a 5.5 mile-long segment of a western secondary trace. Total right-lateral, strike-slip displacement from the earthquakes amounted to "a few inches" (p. 1), while the main earthquake ($M_R = 5.5$) produced coseismic displacement along the main trace that amounted to 1.8 inches at Highway 46 in the Cholame quadrangle (p. 52-53), and 2 inches at the "Claassen fence" in the Stockdale Mountain quadrangle (p. 33-35).

Brown (1970) shows an annotated "strip map" (scale 1:62,500) of recently active breaks along the San Andreas and related faults between Tres Pinos (San Benito County) and Cholame Valley. The southeastern portion of his fault traces are shown in Figures 2A and 2B. His map incorporates much of the data presented by Brown and others (1967). In the Parkfield-Cholame Valley segment of the fault, Brown shows only the main and western secondary fault traces that ruptured during the 1966 earthquakes, along with extensions of the main fault trace to the northwest and southeast.

Lienkaemper and Brown (1985) replotted the surface fault-rupture data from the 1966 earthquakes at a scale of 1:12,000, based on Brown's original mapping on 1:3000- and 1:6000-scale air photos. Their map depicts the fault rupture more accurately than the published maps of Brown (1970) and Brown and others (1967), and their fault traces are shown on Figure 3.

Dickinson (1966) mapped the regional geology within and northeast of the San Andreas fault zone in much of the five quadrangles. The Quaternary-age fault traces shown by Dickinson, which were previously zoned by CDMG (see Figures 2A and 2B), include a linear, northwest-trending, main fault generally similar to that shown by Brown (1970), Brown and others (1967), and Dibblee (1971a, 1971b; 1972). Dickinson also mapped numerous sinuous faults that are subsidiary and subparallel to the main fault. He considers the two principal subsidiary faults within Cholame Valley to be northwest and southeast extensions of the main traces of the San Andreas fault. He notes (p. 717) that both of these extension faults offset Holocene alluvium but locally are

concealed by Holocene alluvium. Neither Sims (1985) nor Dibblee (1971a) show the double-trace extension faults northeast of the main trace north of Highway 46 (see Figures 2A and 2B). Dickinson's extension fault along the southwest side of Cholame Valley (Figure 2A) is interpreted to be a surface fault (dashed or solid line) in Holocene alluvium, although Dibblee and Sims show this fault to be largely concealed. To the northwest of Cholame Valley (proper), Dickinson shows this extension fault to offset Holocene alluvium only in the vicinity of the western secondary trace that ruptured in 1966. The broad zone of sinuous faults which lies northeast of the main trace and northwest of Gold Hill are shown by Dickinson locally to offset Holocene alluvium. These faults generally have not been verified by Dibblee (1971a, 1971b) or Sims (1985), and none of these faults are known to be historically active. Dickinson provided CDMG with enlarged versions (scale 1:24,000) of his published maps in 1973. These enlarged maps were used in the initial zoning because his published maps were of inadequate scale. However, he recommended that CDMG zone only the main active traces of the San Andreas fault (Hart, p.c., 1985).

Dibblee (1971a, 1971b, 1972) mapped the regional geology in four 15-minute quadrangles (scale 1:62,500) along the San Andreas fault (see Figures 2A and 2B). Of the numerous Quaternary-age faults mapped by Dibblee (and previously zoned by CDMG), only the main and secondary active fault traces that ruptured during the 1966 earthquakes are shown to have right-lateral, strike-slip displacement. Sense of displacement along other traces is not indicated. Evidence of strike-slip displacement along some of the other Quaternary-age faults (near Middle Mountain and south of Highway 46) consists of bedding attitudes in the Plio-Pleistocene units, with strikes that are parallel to nearby faults. Many of his Quaternary faults are locally concealed by Holocene alluvium (see Figures 2A and 2B), but he shows faulted Holocene sediments along a 1.7 km-long segment of a northwest-trending fault on the west side of Cholame Valley. Dibblee's locations for the main and secondary fault traces that ruptured in 1966 generally are near those shown by Lienkaemper and Brown (1985), but locally are as much as 100 meters away from the latter's fault traces.

Sims (1985) mapped the San Andreas fault zone in Cholame Valley. In the preliminary version of his map of the Cholame Valley quadrangle, which he made available to CDMG, he shows the 1966 surface rupture as mapped by Brown and others (1967). However he believes the fault traces shown by Lienkaemper and Brown (1985) to be more accurately located and will show their traces on his published map (J.D. Sims, 10/11/1985, personal communication). Approximately 300 meters southwest of Gold Hill (see Figure 2A), Sims shows a northwest-trending Holocene fault that connects segments of the 1966 fault trace. He states (p.c.) that the trace is based upon field observations of warped and deformed terrace strata, a wet spot, and a low, southwest facing scarp. Two kilometers further to the northwest along the main trace, he shows faults along the east bank of Cholame Creek and in the adjacent hills. This fault is not plotted on Figure 2A but is the same as mapped by Dickinson (1966). Sims states (p.c.) that evidence for these traces are the linear creek bank, and a northwest-trending linear trough immediately north of the creek. [Air photo interpretation by Manson (this report) indicates that the linear trough may be due to movement of a south facing landslide at that location.] Sims also shows a zone of several southeast-trending faults near

the west side of Cholame Valley south of Cholame Ranch, in latest Pleistocene to Holocene alluvium and fan deposits (see Figure 2A). These latter faults were not previously recognized or zoned.

San Juan Fault (north extension)

South of Cholame and west of the San Andreas fault in the Cholame quadrangle (Figure 2B) is the San Juan fault (Dibblee 1972, 1974). Dibblee interprets the San Juan fault as being a right-lateral, strike-slip fault with significant truncation of the Paso Robles Formation and older units. The fault locally is shown to truncate Holocene and Pleistocene alluvium south of the Cholame quadrangle, but this may be a drafting error as these same units are not shown to be truncated elsewhere. Within the Cholame quadrangle the youngest unit offset is the Paso Robles Formation; the fault is concealed where Holocene alluvium is present. Although San Juan Valley to the south appears to be right-laterally offset, the smaller, younger drainages are not systematically offset by the fault. Jennings (1975) shows the San Juan fault, including its northern extension in the Cholame quadrangle, to have a total length of about 66 km (41 miles). Zoning of the fault is restricted to the segment within the Cholame quadrangle because it is the only segment within the same quadrangle as the San Andreas fault.

AIR PHOTO INTERPRETATION AND FIELD OBSERVATIONS

Four sets of black and white air photos were available to the author: USDA (1949; 1956) and USGS (1966, scales 1:3,000 and 1:6,000). These photos covered the San Andreas fault, but not the San Juan fault. No air photo interpretations or field observations were made for the San Juan fault. Field observations for the San Andreas fault were made by the author on 23 August 1985, and were limited to areas near public roads south of Middle Mountain (see Figure 3). Earl Hart assisted the author in air photo interpretation and field observations.

San Andreas Fault

The active main and secondary traces of the San Andreas fault can be followed on the air photos as generally well-defined alignments of fault-related geomorphic features (right-laterally deflected drainages, shutter ridges, linear troughs and drainages, sidehill benches, closed depressions, scarps, tonals, and saddles or notches). These features were mapped in detail in the Stockdale Mountain, Parkfield, and Cholame quadrangles where the 1966 fault rupture was discontinuous or not reported. The locations of fault-rupture shown by Lienkaemper and Brown (1985) were generally verified on the air photos by the existence of fault-related geomorphic features (see Figure 3).

Locally, both the main and secondary active traces become difficult to follow on the air photos. The main trace is partly obscured by massive landslides on the northeast side of Middle Mountain, and by erosion and sedimentation in Cholame Creek near Gold Hill. In Cholame Valley, the main trace has a "right stepover" across Cholame Creek. Although no fault rupture was noted in the "stepover" segment following the 1966 earthquakes, north- and northwest-trending tonals in the late Holocene alluvium appear to connect the two fault traces. The western secondary active trace is not as well-defined

on the air photos as the main trace, and had only minor discontinuous surface rupture during the 1966 earthquakes (see Figure 3). Northwest of the road between Parkfield and San Miguel, at the northwest end of the fault rupture, the western trace can be followed as an alignment of linear troughs, closed depressions, deflected drainages, and breaks-in-slope before becoming obliterated by the numerous large landslides on the southwest flank of Middle Mountain. At the south end of the fault rupture, near Covington Lake, the secondary trace continues to the southeast as an alignment of scarps, a deflected drainage, and tonals before dying out in the Holocene alluvium of Cholame Valley.

Northeast of Palo Prieto Canyon in the Cholame quadrangle, a secondary fault lies parallel to and 300 meters west of the main trace (see Figure 3). The fault extends southeastward from the quadrangle. This secondary fault, which was not previously recognized or zoned, can be traced on the air photos as an alignment of scarps, a deflected drainage, and a long, linear trough.

Another secondary trace, defined by a prominent northeast-facing scarp and linear trough, is visible on the U.S.D.A. (1949) air photos 1.8 km southwest of Cholame Ranch (see Figure 3). This 0.9 km-long scarp in alluvium is concealed at each end by modern alluvial fans. Although shown to be a fault by Dibblee (1971a), Dickinson (1966), and Sims (1985), this fault is slightly mislocated to the southwest on their maps.

No systematic evidence of recent faulting in Holocene alluvium was seen on any of the several secondary faults shown by Dickinson (1966) northeast of the main active trace (see Figures 2A and 2B). With the exceptions of the well-defined scarp along the Grant Boundary, and the secondary fault trace that partially ruptured in 1966, no systematic evidence of recent faulting was seen for the other secondary fault traces shown by either Dickinson or Dibblee (1971a, 1971b; 1972) southwest of the main fault trace. See Figure 3 for specific notations.

Most of the faults shown by Sims (1985) in Latest Pleistocene to Holocene alluvium and alluvial fans near the west side of Cholame Valley (Figure 2A), can be verified on the air photos as alignments of scarps, tonals, and linear drainages. The other traces appear to be erosional in origin.

San Juan fault

No air photos were available for the San Juan fault and the fault was not field checked. The topographic map (Figure 2B) reveals right-laterally-deflected ridges and drainages in the N. 1/2 sec. 20 and S. 1/2 sec. 17, but not elsewhere. In addition, some of Dibblee's Holocene deposits in sections 29 and 32 are dissected, and may include undifferentiated Pleistocene deposits where he shows the fault to be concealed. The fault is clearly Quaternary in age, but evidence of Holocene activity is weak and inconclusive.

CONCLUSIONS

1. The San Andreas fault is a major, right-lateral, strike-slip fault which extends northwestward across California for 600 miles, from the Salton Sea on the southeast to Point Arena on the northwest. The fault has a north-trending offshore extension between Point Arena and Shelter Cove.

2. The existing Special Studies Zones include the known active traces of the San Andreas fault as well as other Quaternary-age faults mapped by other workers within the Cholame, Cholame Valley, Cholame Hills, Parkfield, and Stockdale Mountain quadrangles. Because CDMG zoning policy has changed, many of the previously-zoned faults do not meet the current criteria of "sufficiently active and well-defined" (Hart, 1985, p. 5-6).
3. The main trace of the San Andreas fault can be followed northwestward across these five quadrangles as a generally well-defined alignment of fault-related geomorphic features developed in Holocene alluvium, late Quaternary landslide deposits, and rock units of Pleistocene age or older (see Figure 3). Sense of displacement along this trace is clearly right-lateral strike-slip. Most of this main trace ruptured during the 1966 Parkfield earthquakes (Lienkaemper and Brown, 1985), with total right-lateral displacement of "a few inches" (Brown and others, 1967, p. 1). Due to Lienkaemper and Brown's replotting of field data on a larger-scale map, their fault rupture locations are more accurate than those shown by Brown (1970) or Brown and others (1967). Creep displacement also is recorded locally.
4. A secondary northwest-trending active trace of the San Andreas fault, which also ruptured during the 1966 earthquakes, lies to the west of the main fault trace (Brown and others, 1967; Lienkaemper and Brown, 1985). This western trace had less right-lateral displacement during the earthquakes than the main trace and ruptured discontinuously (Brown and others, 1967). Based on fault-related geomorphic features in bedrock and Holocene alluvium (Figure 3), the 1966 traces of Lienkaemper and Brown (1985) can be connected and extended to the northwest and southeast.
5. Northeast of Palo Prieto Canyon in the Cholame quadrangle is a secondary fault that lies parallel to and 300 meters west of the main trace. This secondary fault appears to be recently active and can be followed as an alignment of scarps, a deflected drainage, and a long, linear trough.
6. Another secondary fault southwest of Cholame Ranch appears to be active and is well-defined by a prominent scarp and linear trough. However, it cannot be extended as a surface feature to the northwest or southeast.
7. In the western part of the Cholame Valley quadrangle, at the Monterey County boundary, a zone of several short, discontinuous, northwest-trending fault traces were mapped by Sims (1985) in latest Pleistocene to Holocene alluvium. Most of his fault traces are moderately well-defined by scarps, tonals, and linear drainages that are suggestive of Holocene activity. However, two of the traces appear to be erosional in origin.
8. Dickinson (1966) shows several curvilinear, northwest-trending Quaternary-age and Holocene-age faults northeast of the main fault trace. These traces are poorly defined and could not be verified on the air photos as being active faults (Figures 2A and 2B). Other previously-zoned faults of Dickinson (1966) and Dibblee (1971a, 1971b; 1972) could not be verified as being active faults (Figures 2A and 2B).
9. The San Juan fault is a significant, north-to northwest-trending fault that lies to the west of the San Andreas fault (Jennings, 1975). Dibblee

(1972, 1974) interprets the north half of the San Juan fault to have right-lateral, strike-slip displacement. The youngest unit shown by Dibblee to be faulted is the Paso Robles Formation, with possible local truncation of Holocene and Pleistocene alluvium south of the Cholame quadrangle. In the Cholame quadrangle, part of the fault is shown to be concealed by Holocene alluvium, which may include Pleistocene deposits locally. Because there are no air photos in the possession of CDMG that cover the north end of the fault, no photo interpretation has been done, and possible evidence of the fault's late Quaternary activity may not have been noted. However, no evidence of systematic displacement of ridges or young drainages is indicated on the topographic map.

RECOMMENDATIONS

Existing Special Studies Zones within the Cholame, Cholame Hills, Cholame Valley, Parkfield, and Stockdale Mountain quadrangles should be revised as follows:

- 1) Remove traces of the San Andreas and associated faults shown by Dibblee (1971a, 1971b; 1972) and Dickinson (1966).
- 2) Relocate the main and secondary fault traces of Brown (1970) and Brown and others (1967), using the fault traces of Lienkaemper and Brown (1985).
- 3) Extend the fault traces of Lienkaemper and Brown, as shown in Figure 3 of this report.
- 4) Add secondary fault traces as shown in Figure 3 of this report.
- 5) Delete the northern end of the San Juan fault in the Cholame quadrangle. Air photos of this fault should be checked to verify this recommendation.

References cited for the Stockdale Mountain, Parkfield, and Cholame Hills quadrangles should be Lienkaemper and Brown (1985) and this report for fault location, with supporting data provided by Brown (1970), Brown and others (1967), and Schulz and Burford (1979). References cited for the Cholame Valley quadrangle should be Lienkaemper and Brown (1985), Sims (1985) and this report for fault location, with supporting data provided by Brown (1970), Brown and others (1967), and Schulz and Burford (1979). References cited for the Cholame quadrangle should be Lienkaemper and Brown (1985) and this report for fault location, with supporting data provided by Brown (1970) and Brown and others (1967).

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*Recommendations
approved.
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11/22/85*

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